AD-770 113

AFRRI ELECTROMAGNETIC PULSE (EMP) SIMULATOR

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Bethesda, Maryland

September 1973

UNCLASSIFIED
Security Classification

AD 770 113

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Armed Forces Radiobiology Research Institute Defense Nuclear Agency Bethesda, Maryland 20014	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP N/A

3. REPORT TITLE

AFRRI ELECTROMAGNETIC PULSE (EMP) SIMULATOR

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

5. AUTHOR(S) (First name, middle initial, last name)

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6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
September 1973	12	1

8a. CONTRACT OR GRANT NO. b. PROJECT NO. NWED QAXM c. Task and Subtask C 903 d. Work Unit 09	9a. ORIGINATOR'S REPORT NUMBER(S) AFRRI TN73-14 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Director Defense Nuclear Agency Washington, D. C. 20305

13. ABSTRACT

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DD FORM 1 NOV 65 1473

UNCLASSIFIED
Security Classification

/a

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AFRRI TN73-14
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ACKNOWLEDGMENT

The authors would like to acknowledge the contribution of many who have made it possible to begin the animal exposures only 8 months after biology electromagnetic pulse data were requested. Particular mention is made of A. E. Andrews and W. Youngblade, both of DNA Headquarters; many staff members of the Electromagnetic Effects Laboratory of Harry Diamond Laboratories, Woodbridge, Virginia; J. Leib of Braddock, Dunn and McDonald; and P. Champney of Physics International Company, all of whose respective skills contributed greatly to a successful facility. Much of the work associated with the fabrication of the transmission line and the contracting of the shield room was handled by H. B. Cranford of AFRRI in a most efficient manner. The contribution of R. E. Severance of AFRRI in the final testing and shakedown phase was invaluable and was crucial in meeting a tight schedule.

TABLE OF CONTENTS

LIST OF FIGURES

ABSTRACT

An electromagnetic pulse simulator for animal studies has been built and operated at AFRRI since September 1972. The exposure volume consists of a terminated parallel-plate transmission line fed with a pulse the time dependent wave form of which can be approximated by a double exponential. Peak electric field strengths up to 500 kV/m are available at a repetition rate up to 7 pps.

I. INTRODUCTION

Nuclear explosions generally produce a short, intense electromagnetic pulse (EMP) which, depending on the altitude, can radiate over many hundreds of miles. This pulse is produced by a flow of Compton electrons generated in the atmosphere as the front of gamma rays from the burst interacts with the air molecules. Because of the very short rise times (~ 10 nsec) and large amplitudes of the EMP, large voltages and currents can be induced in conductors exposed to the electromagnetic fields. It was found in the early phases of nuclear weapons testing that cables and electronic test equipment could be upset or damaged by the energy contained in the EMP; hence, EMP represents a threat to communication systems. missile guidance devices, computers, etc.

The understanding of EMP, its interaction with weapon systems and the prevention of damage, has, therefore, been a matter of great importance and concern in national defense. The restrictions on atmospheric nuclear testing have made it necessary to construct simulators of an electromagnetic environment relatable to that produced by this type explosion for the empirical investigation of military hardware, ranging from small electronic components to large airplanes and ships.

While it is not immediately obvious or certain that biological effects could be induced in personnel exposed to repetitive EMP fields produced by any of these simulators, it is prudent to investigate the possibility thereof. The questions are similar to those arising when biological systems are exposed to pulsed microwave fields, a potential hazard receiving much attention at the present time.

To study biological responses to EMP fields under adequately controlled conditions, an EMP simulator especially designed for biological studies has been constructed at AFRRI.

II. AFRRI SIMULATOR SYSTEM CONCEPT

In considering EMP effects on man, one should distinguish the following three situations: (1) a person in contact with or near an extended conductor which acts as an efficient antenna, (2) a person in the electromagnetic field and grounded to earth, and (3) a person in the electromagnetic field but insulated from ground. The first two situations are similar and differ only in the magnitude of the electrical current that might flow through the body and the absorbed frequency spectrum. In the third situation no net current flow in or out of the body is possible. While all three situations can exist, only the third one is being studied initially in the AFRRI simulator.

Considerations of geometry and coupling between electromagnetic fields and a biological system as well as the physical parameters of the system, such as dielectric constants, conductivity and capacitance, lead to the immediate conclusion that for a body insulated from ground, current flow and thermal heating due to energy absorption from an EMP field do not pose a hazardous condition. However, the question of biological effects cannot be answered by considering a living system to be merely the sum of its physical components. Furthermore, it must not be assumed that the amount of energy absorbed is the only factor which can cause system changes. There are many ionic and electrochemical processes in a living organism the delicate balance of which is vital to normal functioning, and it is conceivable that changes in these processes could be evoked by an electromagnetic field. The biological system could act as an

amplifier and then react strongly to the external stimulus. Most likely, however, such effects would be transient behavioral changes rather than pathological damages.

In the experimental design it was decided to test animals in an environment which was excessive in terms of peak electric field, pulse rise time, and pulse repetition rate in order to amplify any measurable changes. This was particularly important in view of the differences in geometry between man and the animal model (small rodents), and the fact that no prior evidence exists to indicate which parameters of the electromagnetic field would be most important.

III. SIMULATOR SYSTEM DESCRIPTION

The actual simulator system consists of three parts: (1) the transmission line which contains the animal exposure volume, (2) the pulser network, and (3) the system controls. The transmission line and the pulse generator including the high voltage power supplies are contained in a shielded room approximately 3-1/2 meters wide by 13 meters long and 3 meters high. The control console is located in a separate room next to the pulse generator. Power cables are connected to the high voltage supplies through low-pass RFI filters. Control and monitoring cables and gas control lines are connected to the pulser through a bulkhead feed-through panel between the shield room and the control room.

<u>Transmission line</u>. The transmission line consists of two parallel aluminum plates 122 cm wide and 10 meters long with a separation of 56 cm. Four-inch diameter roll-ups are provided around the edges of the parallel-plate system to suppress corona and to "straighten" the field lines at the edges of the exposure volume thereby making the exposure field more uniform. The impedance Z_c of an isolated transmission line

is given by

$$Z_c = \eta \frac{a}{b} \left\{ 1 + \frac{a}{\pi b} \left[1 + \ln \frac{2\pi}{a/b} \right] \right\}^{-1}$$

where η = 377 Ω, a = plate separation, and b = plate width. For these numbers, the line impedance is calculated to be Z_o = 113 Ω.

The transmission line volume (Figure 1) contains two shelves to hold the animal cages. The cages, animals, food and water bottles reduce the line impedance, as does the coupling of the field with the surrounding conducting shield room. Careful model measurements were made to determine these effects. The effective line impedance was thus determined to be about 95 Ω. The transmission line is terminated with a bank of solid high voltage resistors to absorb and dissipate the energy contained in the EMP pulse.

Pulser. The pulser network (Figure 2), excluding the high voltage power supplies, is contained in a fiber glass vessel pressurized to about 1 psi of SF_6 gas. The gas serves as an insulating atmosphere and as a coolant which circulates from the vessel through a heat exchanger and back into the vessel. Two banks of energy storage capacitors, each consisting of two tubular high voltage, 5-μF capacitors in parallel, are charged to ±125 kV, respectively through two 5-kΩ charging resistors from two individual high impedance voltage sources. The capacitors are connected through a pressurized spark gap whose electrode separation is adjustable. The breakdown of the gap is initiated by a trigger pulse of about 100 kV applied to a trigger pin coaxially mounted in one of the electrodes. The gas used in the spark gap housing is nitrogen at about 100 psi. Initially SF_6 was used allowing operation at about 20 psi. However, the

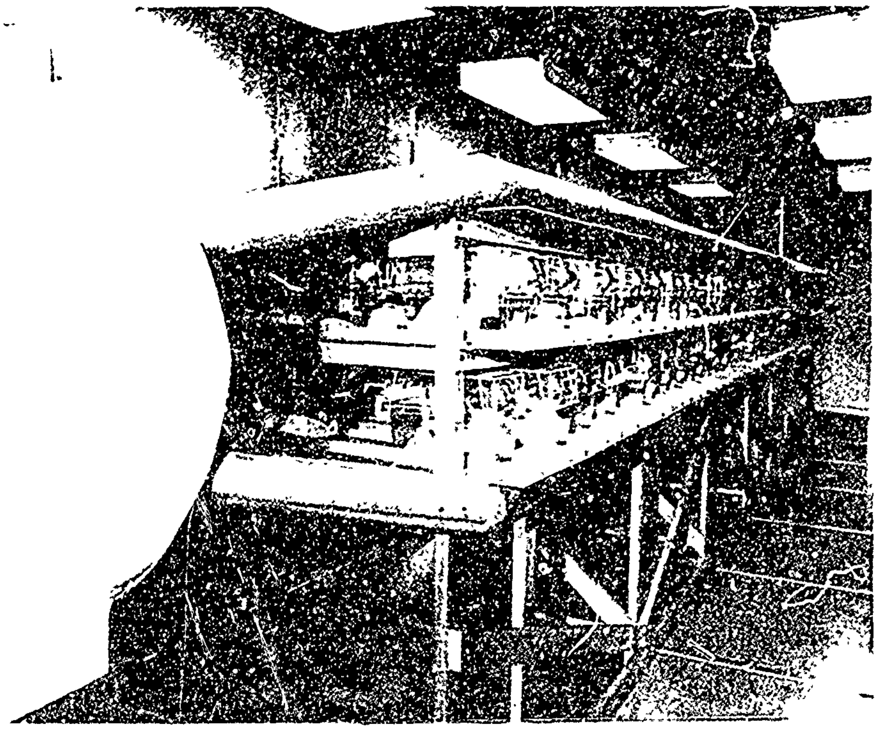

Figure 1. View of pulser vessel and parallel-plate transmission line with animal cages

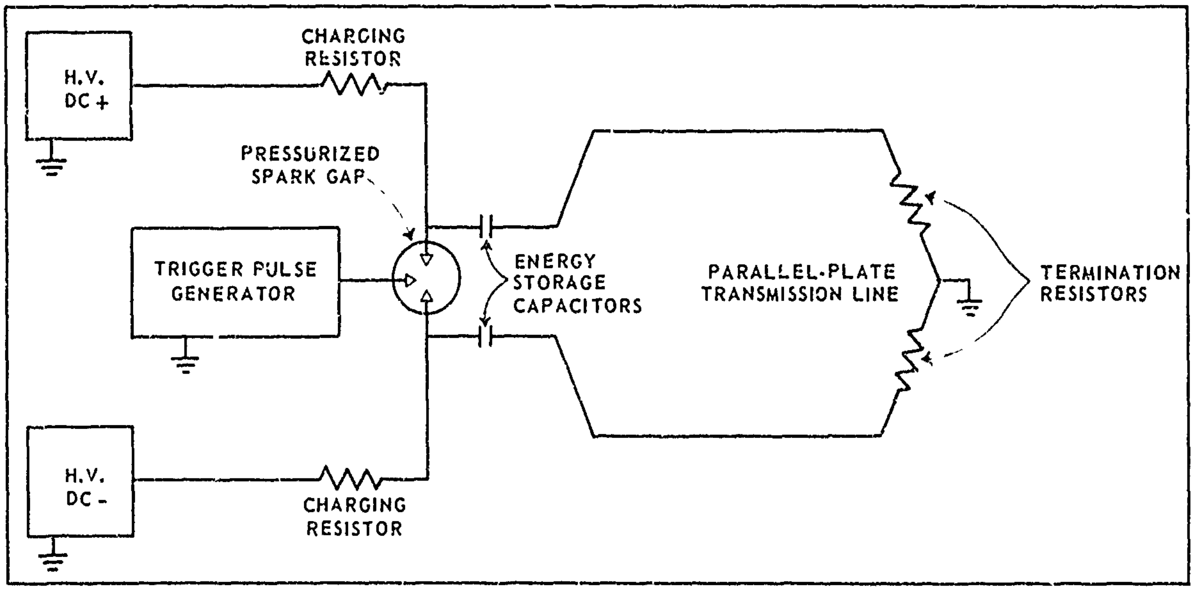

Figure 2. Schematic diagram of AFRRI EMP pulser with terminated transmission line

breakdown products of SF_6 were found to be highly corrosive to the plastic insulating material surrounding the trigger pin and to the O rings sealing the gap housing.

System controls. All controls, except the spark gap adjustment, are located in the control room. Two cabinets contain the power control for the high voltage supplies, a power supply for the gap trigger pulse, the trigger frequency generator and control, and the control for vessel and spark gap gas pressures. An elapsed time clock records the total system on-time, and a nonresettable register displays the number of fired pulses. The system can be used for single shots and for continuous pulsing at variable repetition rate. The system is interlocked to fail-safe in case of overcurrent or over-voltage in the HV supplies, overpeak and underpeak voltage, or high temperature and low gas pressure in the pulser vessel. A safety door interlock shuts down the system in case of entry to the shield room.

System specifications

transmission line:	parallel plates, 122 cm wide, 10 m long, 56 cm separation, 95 Ω impedance (with animal load and in shielded room)
power supply:	two ± 150 kV dc supplies
energy storage capacitors:	four 5-nF tubular capacitors, two series banks of two parallel capacitors; total capacitance in banks 5 nF
spark gaps:	triggered, pressurized switch
pulse shape:	double exponential (Figure 3)
rise time:	4-5 nsec (10-90 percent)
fall time:	550 nsec (to 1/e of peak)

peak field strength:	10-500 kV/m
pulse repetition rate:	up to 7 pps; single shot
energy per pulse:	160 joules maximum
field power density:	66.3 kW/cm^2 peak (at 500 kV/m)
system line impedance:	95 Ω
spectral content:	double exponential (Figure 4).

Field monitoring. The EMP field is monitored with a $\dot{B}$ sensor which can be placed at any point in the exposure volume. The integrated signal is read out on an oscilloscope in the control room.

Operations. The system is designed to operate continuously 24 hours a day, 7 days a week with minimum maintenance. Short shutdown periods are scheduled on 4 days a week for animal care and to obtain biological samples. After initial problems

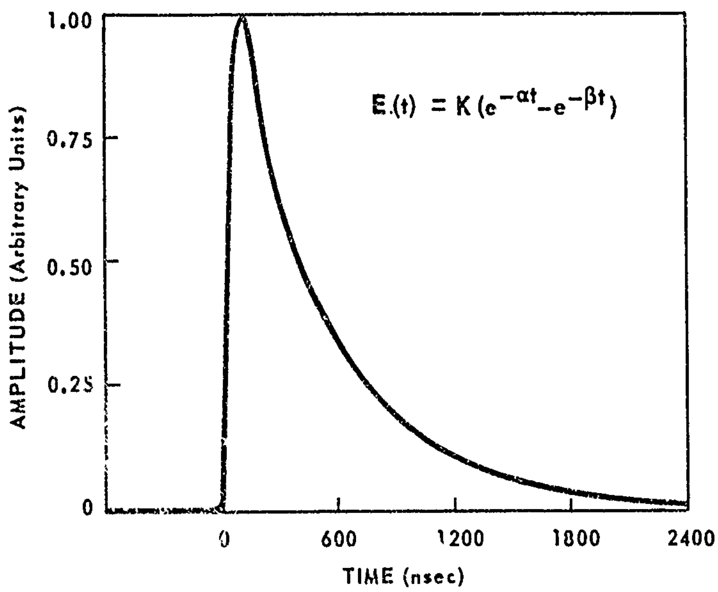

Figure 3. Typical EMP pulse calculated as double exponential, $E(t) = K(e^{-\alpha t} - e^{-\beta t})$, using the actual circuit parameters

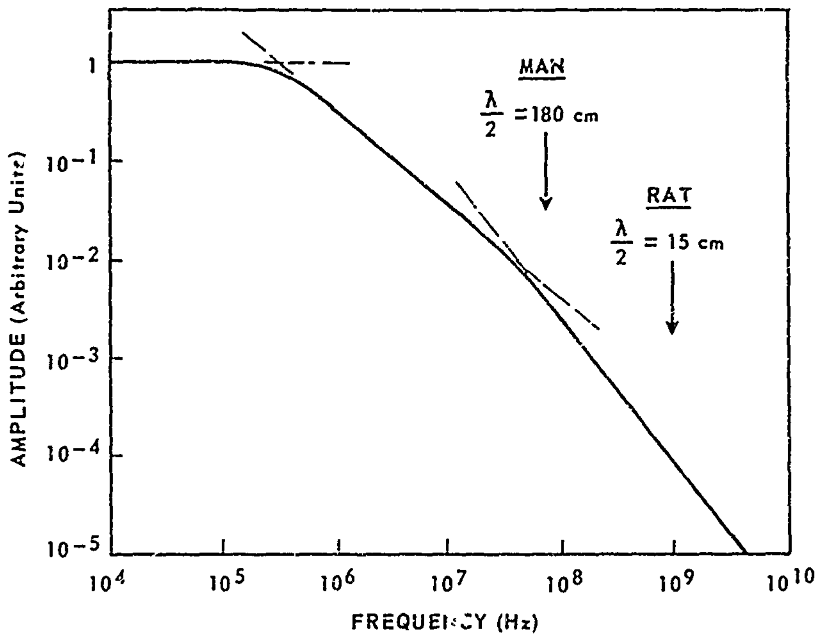

Figure 4. Fourier frequency spectrum calculated from the double exponential shown in Figure 3. Arrows indicate those frequencies for which $\frac{\lambda}{2}$ is equal to the average height of man and the average length of a rat, respectively.

with the trigger system, the spark gap, and HV cable breakdowns, the system is now very reliable and operates about 95 percent of elapsed time at five pulses per second at maximum field strengths of 500 kV/m.

On 11 May 1973, the animals under test had been exposed to approximately 80×10^6 pulses. An interim report on the responses of two animal species to EMP exposures has been completed.[1]

REFERENCE

1. Skidmore, W. D. and Baum, S. J. Biological effects in rodents exposed to pulsed electromagnetic radiation. Bethesda, Maryland, Armed Forces Radiobiology Research Institute Scientific Report SR73-10, 1973.

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